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ABSTRACT

The purpose of this paper was to examine the literature in an effort to describe the present status of planetarium research and to suggest questions for future research. In an effort to present information related to the historical development, various models of the universe are discussed and information relating to planetarium operators and the philosophy of planetarium usage is presented. A review of associated research includes descriptive studies, comparative studies, curriculum studies, and others. An extensive reference list is included in the paper. (EB)

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THE PLANETARIUM IN EDUCATION

A Review of the Literature

Submitted by

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INTRODUCTION

The planetarium is a sophisticated instrument designed to duplicate the motions of the celestial bodies in an effort to render complicated concepts into a simpler form. Its development and acceptance into the educational scene has been a remarkable occurrence. Ever since its conception, it has been heralded as a marvelous aid for teaching astronomical concepts. Unfortunately, the bulk of praise for the planetarium represents purely subjective opinion. Although several hundred planetariums (representing an investment in the hundreds of millions of dollars) have been constructed in this country alone, there has been until rather recently little research conducted to determine if they are actually a valuable asset in the teaching of astronomy. In view of the large amount of money involved, this is an amazing circumstance. The instrument is certainly charismatic in its ability to attract followers and financial supporters.

Some aspects of planetarium research are still in their infancy period, others are at the adolescent stage and only a few are reaching maturity. This type of research needs much refinement before it can be considered as sophisticated as research in the natural sciences.

Planetarium research has essentially been either of the descriptive survey or the comparative type. The descriptive survey has attempted to describe the status of planetarium procedures at various stages of planetarium development. The comparative study compares the effectiveness of the planetarium to the classroom situation. Unfortunately, in most comparative studies no single factor is isolated as the critical variable.

Thus, comparative studies will usually conclude either in favor of or against the planetarium, but never provide information as to which of the multitude of factors operating in the planetarium have assisted or retarded the learning process with respect to some behavioral objectives.

As a result of the vastness of the planetarium domain and the relatively few number of research studies in comparison, it has been extremely difficult to locate and summarize several articles pertaining to the same concept. While all the articles deal with the planetarium, their content was so varied that the only way to establish an assemblance of continuity was review the literature on a chronological basis. In this manner it was at least possible to show how the studies have contributed to the development of knowledge about the planetarium. The questions which needed answers most urgently were the topics of the initial studies. As the area became more advanced, the studies became increasingly specific and of better design.

Due to the planetarium's unusual development a variety of questions have arisen as to the exact role of the planetarium and in what direction its philosophy should evolve. It was the purpose of this paper to examine the related literature in an effort to describe the present status of planetarium research and to suggest questions for future research.

HISTORICAL DEVELOPMENT

Models of the Universe

The records of nearly every civilization contain evidence of a fascination for the beauty of the skies. This fascination has often led to an attempt to explain the complex and often confounding motions of the stars, planets, comets, and meteors that may be observed in the night sky. The efforts to recreate these motions in a fashion that appeared simple and immediately comprehensible led to the construction of a multitude of simulators of the heavens of which the planetarium is the most recent and sophisticated.

Of the many static models created to depict and explain the motions of the celestial objects some have been preserved for their pure artistry, and most indicate a rather good comprehension of the planets, sun, and moon. Anaximander, who lived in the first half of the sixth century B. C., is credited with inventing a type of celestial globe on which the constellations were depicted. The Farnese Globe, dating back to 75 B. C., represents the best preserved example of this artistry. It is a white marble statue of Atlas supporting the world with the constellation figures and the path of the sun carved in relief on its surface. Other globes containing the Equator and the Tropics of Cancer and Capricorn can be found to represent nearly every century of the Christian Era. These globes all give the reverse representation of the sky. The observer views the stars as if he were located in a position outside of the galaxy.

Various dynamic mechanical models showing the relative motions of the sun, moon, and planets have been constructed since the seventeenth century. A device of this type was constructed in England for Charles Boyle, the fourth Earl of Orrery (1676-1731), and the name "orrery" is still used to refer to this type of apparatus. This device consisted of a series of globes which represented the planets and the sun. Each globe was supported by a metal rod and interrelated by gears at the central pedestal. Some later orreries contained planetary satellites and properly related their motions to those of the planets. Their complexity can readily be appreciated.

The most recent variation of the orrery was constructed in 1913 for the Deutsches Museum in Munich. Attached to the center of the ceiling of a room almost forty feet in diameter was a "sun" globe, ten inches in diameter which provided illumination for the entire room. Other spheres representing the planets moved around the sun with speeds proportionate to their nature velocities. A single-passenger carriage was attached to the sphere representing earth. An observer riding in the carriage would view through a periscope the planets as though lighted by the sun against a background of constellations painted on the walls of the room. Of course, all comparative sizes and distances were distorted, and unfortunately, only one observer at a time could ride in the earth carriage.

A radical departure from the usual orrery models which positioned the observer outside of the universe can be seen in a device known as the Gottorp Globe. One of the oldest examples of this type and one which has

been preserved almost in its entirety was built in the years 1644-1664 for Duke Frederick III of Holstein. This instrument was a huge copper sphere almost twelve feet in diameter and weighing over three tons. It was large enough to allow ten people to be seated inside. The audience would view the stars and constellations which were painted on the inner surface. The stars were illuminated by small oil lamps located near the center of the globe. In addition, the globe was rotated by water power to simulate the motion of the earth. About 1670, Erhardt Weigel of Jena made a similar globe ten feet in diameter. Inside it there were many accessories with which it was possible to reproduce the phenomena of meteors, rain, hail, lightning, and thunder.

In the eighteenth century, Roger Long, professor of astronomy at Cambridge, constructed an "Astronomical Machine" which was quite similar in basic design to the Gottorp Globe. Its interior platform accommodated about 30 people and the stars were represented by holes punched into the 18-foot sphere. The sphere was placed in a lighted room and the light entering the holes appeared to be stars shining. A light source representing the sun could be moved to simulate the sun's motion along the ecliptic. The last globe of this type was constructed in 1911 for the Chicago Academy of Sciences and is known as the Atwood Globe. It was 15-feet in diameter, electrically driven and could demonstrate the motions of both the sun and moon.

Shortly before World War I, Dr. Oskar von Miller, director of the Deutsches Museum of Munich, Germany, asked the Carl Zeiss optical firm at

Jena to work out the most realistic way to bring the heavens indoors for hundreds of visitors at a time. The apparatus he envisioned was similar to a gigantic Atwood globe. The Zeiss engineers worked on the idea, but after a while concluded that it was impossible to physically construct. The company's Dr. Walter Bauersfeld then thought of a new approach. The idea of a great dome was retained but he suggested that it remain stationary and instead use a picture projector to cast an image of the sky on it. Then only the projector and not the dome would have to rotate. In August, 1924, after nearly five years of design and construction, the first modern planetarium instrument was produced. The illusion of reality surpassed the expectation of von Miller and even of the Zeiss people themselves.

Although the prototype instrument was limited in latitude motion and had only one spherical star projector, these faults were soon corrected. The improved projection apparatus was about twelve feet long, with a large globe at each end. Each globe contains projectors for the fixed stars, one for the Northern Hemisphere of the sky and another for the Southern. The dumbell-shaped device has since become synonymous with popular astronomy-lecturing. Twenty-five of these later models were soon built; most of them were installed in Europe, but six were erected in the United States during the years 1930 to 1949.

Until the late forties the number of planetaria in the United States remained small and the facilities were usually of either the municipal or museum type. Although the planetarium was regarded as a marvelous instrument, its high cost prohibited wide distribution. In 1947, Armand

N. Spitz became the "Henry Ford" of the planetarium industry. He made it possible for every school to afford a small planetarium. Zeiss brought the stars to the city but Spitz brought them into the classroom. The development of the Spitz planetarium projector, which utilized the principle of pin-hole projection, reduced the cost of the planetarium to about one-tenth the cost of a Zeiss projector. By the mid-fifties, over 150 Spitz planetariums were installed in schools, colleges, and museums around the world. The educational possibilities of a classroom sized planetarium were soon to be expounded.

Planetarium Operators

For maximum effectiveness an educational tool needs to be placed under the direction of a teacher who knows how to utilize its capabilities to the fullest extent--even to inventing new applications. The need for teachers who are trained to teach in a planetarium environment is now recognized. Until recently, it has been a case of trial and error for the teacher who was told by the principal of the school, "You have been chosen to operate the planetarium." Biology teachers, physical education instructors, English teachers, music teachers, and similarly unprepared individuals have suddenly found themselves with the responsibility of running the school's planetarium. They were expected to illustrate and elucidate the marvels of space travel and the universe before an audience of students and colleagues. In many cases, this was a very trying experience for the non-space-oriented teacher.

However, various agencies have come to the rescue. Handbooks, teacher-guides, lesson plans, and supplemental visual aids are now offered by some planetarium manufacturers. Seven planetarium associations have been formed in the United States and Canada and they are a source of assistance to the planetarium teacher through their regional meetings and publications (Chamberlain, 1968; Gilchrist, 1970; Sky & Telescope, 1969). A national organization was also established to further communication of ideas between the regional associations (DeGraff, 1969). Teacher institutes, funded with governmental assistance, and held at various planetariums in the summer and also during the year are another aid. Also, some planetariums are presently offering apprenticeships for those interested in public or museum planetarium work (Jettner, 1973). Finally, the new degree programs in planetarium education offered by sixteen universities provide educational opportunities in a more formal basis for the prospective planetarium educator. Both B. S. and M. S. degrees are available in the area of planetarium education (Hagar, 1973; Jettner, 1969, 1973; Powers, 1973).

Philosophy of Planetarium Usage

The European view of the planetarium which prevailed during the late twenties and early thirties portrayed it essentially as an educational tool; a marvelous teaching aid for the dissemination of astronomical knowledge. The planetarium lecture delivered in a classroom style by either a university professor or research astronomer was limited to demonstrations of the sky from an earth-centered view. Emphasis was placed upon

star identification, planetarium motions, aspects of the sky from different latitudes, and what might be called spherical astronomy.

During the forties planetarium demonstrations were usually limited in the United Stated because of the war. In Europe and Japan, the only other places where planetariums had been constructed, the planetaria were used primarily for celestial navigation training for service personnel. Planetariums in the United States were also enlisted for this purpose--one of the many areas in which the planetarium excels as a teaching device.

The planetarium began to feel its strength and potential during the fifties. The Carl Zeiss firm, now in West Germany, resumed production of planetarium instruments and several other manufacturers were also entering the business. New Zeiss planetariums were established in Chapel Hill, Sao Paulo, Tokyo, Hamburg, and London. Also during this period custom-made planetarium projectors were installed in San Francisco's A. F. Morrison Planetarium (the Academy projector); and in Boston's Charles Hayden Planetarium (The Korkosz projector). The planetarium enterprise was growing. (By June of 1968, there were to be at least eight comparies manufacturing planetariums on a regular basis (Hagar, 1969)).

Also during this period, the educational planetarium came into being as a result of the Armand Spitz pin-hole projection planetarium. The educational possibilites of a classroom sized planetarium were being realized and in the classroom setting the planetarium became more versatile than ever. The planetarium was used as a teaching aid in astronomy,

geography, mathematics, and other physical sciences. Imaginative teachers even found uses for the planetarium in illustrating concepts of art, literature, history, philosophy, and psychology.

In communities without a major planetarium, the small planetarium came to have two roles: one as a classroom of space, and the other as a community planetarium. In some instances the small planetarium put on public shows which rivaled large installations in showmanship and entertainment value and, of course, with the usual educational "fringe benefits."

Most planetariums associated with museums and other educational or scientific institutions were not in the business primarily for profit. Nevertheless, it was soon discovered that when the planetarium put on shows that were interesting to the public the attendance increased and good planetarium attendance yielded monetary gain--at least to the extent of offsetting expenditures. Therefore, a new philosophy of planetarium programming emerged: make it a show rather than a lecture. Dr. Dinsmore Alter, director of Griffith Planetarium at the time, was at the vanguard of the movement to change the image of the planetarium demonstration from that of a musty lecture-hall environment. Alter (1941) stated that it is necessary that the demonstration give a strictly scientific account of the celestial phenomena, dramatized, however, in order that it may appeal to people who know no astronomy at all and thus cause them to come to an entertainment from which they will profit.

Some planetariums, however, found it difficult to achieve the proper blend of science and entertainment, or education and dramatic effect. In

attempting to avoid the pedantic lecture-hall stigma of previous years, some planetariums went too far in the other direction. There was often too much of the "spectacular" without the necessary educational substance. Special effect projections often conveyed the impression of effect for the sake of effect or gadgetry for the sake of gadgets. Those directors fortunate enough to have good shop facilities were able to design and fabricate special projectors which gave realistic presentations of a trip to the moon, the earth as seen from the moon, lunar landscapes, and so forth. Others, with limited shop facilities, sometimes were able to create good effects. More often though, the effects were poor, artificial, and in no way matched the realism or accuracy of the planetarium projector and its motions (Hagar, 1969).

This was a period of experimentation. It meant abandoning the traditions of the past and trying new techniques and daring concepts. Planetarium personnel were reaching out to grasp the full potential of their medium. There was a growing realization among planetarium lecturers that what they really sought was a bit of what they already had. It was the blend that was important. The scientific integrity of the lecture hall, the realism and accuracy of the planetarium projector, and one more ingredient, the theater, represented the planetarium environment.

Armand N. Spitz (1959) sensed this broader significance of the planetarium when he stated that the concept "planetarium" connotes a multi-dimensional experience and in this light must be differently planned and executed than any single facet operation. It is more or less like the "theater" including every detail that goes to make up the experience.

Hagar (1969) suggested that the planetarium-as-theater is not drama merely for the effect of drama; not entertainment for the sake of entertainment; not even science for the sake of science, but it is an elucidation of the scientific endeavors of man in his quest for an understanding of the worlds of space and time in a planetarium setting which is interesting, inspiring, and educational.

The planetarium of the sixties was much broader in concept and vision than was ever realized in the twenties and thirties. The planetarium was more than a machine; it became a theater of space. In a larger sense, it functioned as an astronomical information center; a communication agency between the astronomer on the mountaintop and the man in the street.

To remain abreast of today's world, the planetarium staff may be required to put greater emphasis upon the investigative process of the scientific enterprise in their planetarium programming. The "what" of space may have been the legitimate presentation for planetarium's clientele in past decades; but for the student of today it may not suffice. There is nothing wrong with a spectacular planetarium program but in the past very little lecture time was devoted to clarifying why and how astronomers can arrive at different interpretations of the same observations.

Looking toward the future, the planetarium may have a potential for education which is far beyond the dreams of its inventor, Walter Bauersfeld. The success of the planetarium of tomorrow lies in the long-range goals which those in the planetarium trade set today (Bennett, 1969;

Lovi, 1969). In order to properly establish realistic goals it is necessary to conduct research on planetarium education in an effort to determine this potential. Only then will it be possible to decide under which conditions the planetarium can be best utilized.

The material in the preceding chapter on the historical development which was not specifically referenced was drawn from the following sources: Bennett, 1969; Berland, 1961; Chamberlain, 1958, 1960, 1962; Chamberlain, 1967; Christian, 1968; [illegible] Hagar, 1969.

REVIEW OF ASSOCIATED RESEARCH

Descriptive Studies

A review of the literature dealing with all aspects of the planetarium has revealed many articles voicing opinions about the value of the planetarium as a teaching aid. Also found were numerous papers describing new and existing planetarium installations, but only a small number, in comparison, dealt with research actually conducted to investigate various planetarium phenomena.

A large portion of the journal articles and doctoral dissertations concerned with planetarium research have been of the descriptive survey type. These studies have attempted to describe the status of planetarium operations at various stages in the development of the planetarium. This type of study was of immense value in light of the newness of the field.

The first doctoral dissertation relating to the planetarium was written as recently as 1962 (Chamberlain, 1962). By this time there were already several hundred planetariums operating in the United States, but unfortunately, most of them were operating completely independently of each other. Each was in a sense having to reinvent the wheel as far as planetarium practices were concerned. Therefore, it was necessary that initial studies be conducted which summarized the status of development of the planetarium and the various techniques of operation. With this information new planetarium facilities could avoid the mistakes made by their predecessors and began to advance the frontiers of education in the planetarium. Unfortunately, the domain of the planetarium is so vast that

descriptive studies still must be conducted before experimental research can be done on many aspects of planetarium education.

The first publications dealing strictly with planetarium related literature first appeared in 1958 and 1960 as a two volume series entitled "Planetariums and their use for education." These volumes represented a collection of papers from the first symposiums concerned primarily with educational planetaria. It was hoped that the papers would aid those in the process of development of new planetariums. The content of these volumes dealt with such topics as: (1) astronomical subjects and applied science, (2) fitting the lecture to the audience, (3) training programs, (4) correlation of the planetarium and the classroom, museum, observatory or astronomy clubs, (5) architectural design, (6) special effects, (7) methods of presentation, (8) press releases, and (9) qualifications and training for planetarium personnel.

These papers were not for the most part a result of research studies but instead an accumulation of knowledge by planetarium personnel discovered through the trial and error process. The articles were of subjective nature and reflected opinions which were planetarium specific, yet they represented the best and most complete source of information relating to the planetarium at the time. The frequency with which these two volumes have been referenced indicates that they were the foundation for all future planetarium activities.

Initially some planetarium lecturers attempted to evaluate the success of a presentation by the "feel" of an audience (Korey, 1963). Also the extent of comprehension and interest was frequently evaluated from

comments and questions during and after the lecture. Letters of appreciation and pictures drawn by younger students which were sent to the lecturer after visits afforded some insight into their reactions and impressions. A few planetariums had experimented with questionnaires, but these had been considered learning devices rather than evaluative instruments.

In order to assist the Washington, D. C. public schools in establishing an educational program using the planetarium, Margaret Noble (1960) conducted a survey of the directors of fifteen planetariums in the United States and Mexico. From the survey she concluded the following:

(1) the visiting class should be studying an astronomy unit when they come to a planetarium and preferably not be at the end of the unit.

(2) teachers can derive benefit from in-service study using the planetarium to study astronomy as well as discovering how the planetarium could be used with existing science and mathematics curricula,

(3) a follow-through visit by the planetarium lecturer was not considered in the usual planetarium programming,

(4) there seemed to be a low correlation between the planetarium lecture content and the school's curriculum which it was intended to complement, and

(5) the planetarium presentations do not always represent learning situations.

As a result of the study, Noble recommended that the planetarium lecturer visit the classroom to prepare the students for the visit to the planetarium. She also found that the greatest number of students attending the planetarium to be fifth graders and that elementary school children came in greater numbers than do secondary school children.

Another study attempting to assess the educational value of planetarium programs by the questionnaire method was conducted by Chamberlain (1962) at the American Museum-Hayden Planetarium during the 1959-1960 school year. After planetarium visits, the teachers were asked to complete a brief check-off-type questionnaire. The results of 1,461 questionnaires which were returned implied the following:

(1) Lecture materials were considered good by 72.2 per cent of respondents.

(2) Eighty-six and two tenths per cent of teachers considered by method of presentation was "interesting and vivid."

(3) Ninety-three per cent stated that the planetarium visit was helpful in the class work.

Unfortunately, while Chamberlain's study indicated that in general students benefit from the planetarium experience in the opinion of their teachers, no measure was made on the students to determine exactly how much they had learned and retained from the lecture. Chamberlain had rejected the idea of evaluating the students on the premise that the teachers would be more likely to give useful responses and for the type of questionnaire which he had designed, he probably was correct. However, the

questionnaire was very superficial in nature and did not explore cause and effect relationships.

Chamberlain's (1962) doctoral dissertation entitled "The administration of a planetarium as an educational tool" was a historical review of various projection devices and a questionnaire survey of ten major planetarium installations in the United States. From this survey (which appears to be an extension of Noble's paper and the articles in Volume I and II of "Planetariums and their use for education") and his own experience, he was able to propose guidelines for planetarium administration. His major conclusion was that the planetarium would attain its greatest potentiel when administered by a professional-trained staff oriented both in astronomy and education. Papers by Branley (1970), Bunton (1968), Crull (1969), Gallagher (1970), Gardner (1964), Geiger (1970), Hagar (1969, 1970), Lovi (1967), Pitluga (1968, 1972), Sunal (1968), Wieser (1970) dealth with topics similar to those in Chamberlain's study and either arrived at or extended approximately the same conclusions.

The value of Chamberlain's study lies in its ability to be used as a manual by those contemplating the construction of a new planetarium facility. He pointed out many of the pitfalls in planetarium operations and provided suggestions on how to avoid them. Chamberlain's only concern was the operation of the planetarium from an administrative standpoint and he did not explore the relationship of the planetarium to education other than concluding that it was a marvelous teaching aid. It remained for Korey (1963) to survey this aspect of the planetarium domain.

Korey (1963) conducted a descriptive survey of 203 planetariums in the United States. She found that formal evaluation procedures had not yet been established and that informal approaches had provided only very limited knowledge about the conveyance of astronomical information and concepts in the planetarium. However, there was great concern for assessment and improvement by planetarium directors.

As a result of the survey, Korey (1963) made the following recommendation:

> "Research is needed to evaluate all phases of class visits to planetariums. So much money has been invested in physical plants and so much time and effort are expended by planetarium and school personnel each time a visit is arranged, that it is essential to discover the most effective way of using the available resources [p. 70-72]."

Results of the study were reported in terms of the percentage of responses to the survey questions about programs and audiences. No attempt was made to place a value upon the contributions made by the planetarium and this was indeed unfortunate since this objective was the goal of Korey's study. Seven years after Korey's study Warneking (1970) found that Korey's conclusions as to a lack of formal evaluation procedures was still appropriate and it appears to this author that as recently as 1973, the status of these evaluations has remained unchanged.

Noble (1964) extended her 1960 study in an effort to examine the educational uses of the planetarium in the elementary school. Using the survey technique, she again found a frequent gap between a planetarium

presentation and the curriculum of which it is a part and that the planetarium presentation did not always constitute a learning situation. However, in this study, she demonstrated that a cause of the gap appeared to be the elementary teacher's lack of training in astronomy and space science. Workshops conducted by her in the planetarium for the purpose of updating science curriculum for the space age were found to increase the correlation between the planetarium lecture and the classroom activities of the teacher.

Moore (1965) went beyond the formal educational setting in order to examine the characteristics of adults that attended and did not attend planetarium programs. His objective was to discover the difference between these two groups of adults. The measurement was in terms of media participation , attitude differences, and vocabulary recognition. The results were as one might hypothesize but provided no information of value concerning any aspect of the planetarium. The planetarium's function in this study was only to divide an adult evening school population into two separate groups.

The only reason for mentioning Moore's study in this paper was to emphasize the low quality of some of the studies which are supposed to represent planetarium research. Many of the studies reviewed failed to arrive at conclusions which were consistent with their objectives. Others were of poor design and often abounded with confounding variables.

In an effort to extend the work of Noble beyond the elementary level, McDonald (1966) conducted a survey to determine the planetarium

practices and procedures among secondary schools throughout the nation. Information was gathered concerning mandated and recommended positions of the state offices of education toward the installation and utilization of planetaria in secondary schools and the actual use of such facilities by schools. In addition, opinions and recommendations concerning the use of planetariums were obtained from recognized authorities in astronomy and compared to the reported school activities. Again, as in the Korey study the results of this survey were given as compilation of percentage statistics describing the status of prevailing practices in the planetarium.

This type of information served only to inform planetarium personnel as to whether or not they were conducting their affairs similar to others in the field. It appears that the attitude of the period was that if most everyone else conducted certain aspects of the planetarium in a specific manner, then the method must be correct. Unfortunately, this was a monkey-see-monkey-do attitude and surveys like those by Korey (1963) and McDonald (1966) tended to reinforce this attitude.

In 1967, Curtin conducted a study which had a similar objective to that of Korey's. Curtin analyzed the astronomy content of planetarium programs presented to school groups. Using thirty-eight tapes and thirty-five questionnaires he classified the questions that were asked by the demonstrator according to Bloom's Taxonomy. All but nine of 413 questions were in the knowledge class. Unfortunately, in this study as in the Moore study the planetarium served only as a setting. Curtin made no attempt

to find a correlation between the type of questions asked and the planetarium lecture (Curtin, 1968).

Another study which contained a poor design was Downing's 1971 doctoral dissertation which was a survey of planetarium directors in relationship to their use of adult learning principles. One hundred and forty-five questionnaire-opinionnaires were used to determine the feasibility, desirability, and utlization of certain principles of adult learning in adult planetarium programs. This study presented the status quo of the implementation of adult learning principles in the planetarium but neglected to evaluate if these principles were applicable to the planetarium setting.

Papers by Dean (1971), Lewis (1969), and Lovi (1970) expanded a portion of the work done by Chamberlain (1962) in the area of instrumentation. Lovi stated that accuracy in the star field is very important and that all projectors should have as high a degree of accuracy built into them as the budget will permit. This recommendation to those constructing new planetarium facilities appears to be to purchase the most expensive planetarium instrument allowed by the available monies. However, Lovi's conclusions represent only subjective opinion. He has not experimentally ascertained that a high precision instrument produces a better learning situation than a slightly less accurate instrument.

Cross (1964) & Dean (1971) went a step beyond Lovi's study in that they dealt with guidelines for the selection of planetarium instruments. The results of Dean's survey, a summarization of 260 questionnaires, are given in the usual percentage form. His questionnaire was concerned with

the opinions planetarium personnel had toward staff, instrumentation and instruction. As is typical of the survey research technique, he did not put forth his own conclusions but instead presented the majority opinion as being represented of sound concepts since they were discovered through the trial and error process.

Some of these studies like Chamberlain's are very essential pieces of work and of great assistance to anyone planning the construction of the planetarium. The fact that dissertations like those of Dean (1971) and Downing (1971), which dealt with rather simple concepts, are still being written and are of value demonstrate that much research concerning the planetarium is still in its infancy. The planetarium profession is yet unclear as to its place in education. It is searching for its orientation and perhaps these and similar studies will help to indicate the direction in which the development of planetarium philosophy should proceed. Studies dealing with the planetarium's potential and the evaluation of its effectiveness with respect to other devices or situations have also assisted in defining the planetarium's role in the educational scene. These studies are considered as experimental and will be discussed in the next section.

Comparative Studies

Considerable interest and enthusiasm have encouraged wide spread use of the planetarium as a teaching device, and teachers have subjectively evaluated its use as a beneficial experience. However, it remains necessary to experimentally determine the value of the planetarium experience,

the methods of presentation, and the curriculum design which will result in maximum benefit to students. As was pointed out by Howe (1959):

> "Dramatically exciting as the use of the planetarium may be, its importance and value as a teaching aid is directly proportional to the degree it helps the teacher accomplish the goal chosen for a particular learning experience [p. 101]."

Korey (1963) in general agreed with Howe by stating that:

> "Formal evaluation procedures have not as yet been established. The directors are concerned with assessing and improving their programs and will doubtless devote more time to appraisal in the future. At the present time, evaluation has been attempted by various informal methods.
>
> "Research is needed to evaluate all phases of class visits to planetarium. ...it is essential to discover the most effective way of using the available resources [p. 70-72]."

While several research studies have attempted to evaluate various aspects of the educational value of the planetarium much remains to be done in the area of formal planetarium evaluative research.

This section of review is concerned with those studies which compare in some manner the planetarium experience to the traditional classroom situation. Unfortunately, in most comparative studies no single factor is isolated as the critical variable. Thus, comparative studies will conclude either in favor of or against the planetarium, but never provide information as to which of the multitude of factors operating in the planetarium have assisted or retarded the learning process with respect to some set of behavioral objectives. In general the design of the comparative study was to compare two groups on the acquisition of certain

astronomical concepts as a function of the number of lessons of instruction received in the planetarium.

One of the first attempts to objectively evaluate the use of the planetarium in teaching astronomy was made in the 1964-1965 school year at the Elgin Public Schools system by Tuttle (1966). He taught astronomy units concurrently in two sixth grade classes in which students were matched by I. Q., chronological age, and reading scores. One class was taught only in the planetarium and the other only in the classroom. Pre-tests and post-tests were used to determine gains as measured by the two and three dimension spatial relations tests from the Multiple Aptitude Test Battery and by a content test constructed by Tuttle. The results, all in favor of the group receiving instruction in the planetarium, indicated: (1) a highly significant improvement in three dimension spatial relations ($p < .01$), (2) a significance difference ($p < .02$) for improvement in two dimension spatial relations, and (3) improvement in the acquisition of content ($p < .05$). This would appear to be very impressive evidence in favor of the planetarium.

However, since a small sample had been employed (N=64), Tuttle (1966, 1968) designed a second experiment for the following year to evaluate the same factors as well as the importance of the frequency of the visits. This study involved 400 sixth grade students who were taught by different teachers using a unit outline to insure uniformity. The content test in this experiment was constructed by the Elementary School Science Project Office. Results of this study indicated no significant difference ($p > .05$) between any of the factors being considered.

There has been much concern for the different conclusions reached in each of the studies. Tuttle attributed the nonsignificance of the second experiment to the variations in teaching between participating teachers. Tuttle's work left room for considerable doubt as to the value of the planetarium experience.

Approximately the same time Smith (1966) conducted a study to compare the effectiveness of a planetarium lecture-demonstration with a classroom lecture-demonstration in teaching selected astronomical concepts at the sixth grade level. The experimental group, consisting of twelve classes, experienced one forty minute lecture-demonstration concerning selected astronomical concepts in a planetarium. The control group, also twelve classes, experienced one forty minute lecture-demonstration in the classroom on the same astronomical concepts. Smith taught both groups and evaluated the Ss immediately following the lecture-demonstration. The evaluative instrument, an objective multiple-choice test constructed by the investigator, revealed a significant difference between groups ($p < .05$) of achievement favoring the group which experienced the classroom lecture-demonstration.

The assumption that this conclusion is valid for the sixth grade level does not necessarily mean that this finding can be generalized to other grade levels. Smith has suggested as does Warneking (1970) that the higher achievement in the classroom may have resulted from the more familiar learning situation existing in the classroom. He has also pointed out the need for further investigation of this problem at the secondary and college levels.

Unfortunately, the validity and reliability of the instrument used in the study can be questioned. The questions on the measuring instrument were constructed by referring to a list of behavioral objectives devised by Smith. While the list of behavioral objectives were analyzed by four science educators, it appears that there was no attempt made to determine if the items on the test actually measured the objectives as stated, or to establish the content validity of the test by submitting it to an astronomer for a critical analysis and suggestions for modification. In addition no effort was made to discover the reliability of the test. These weaknesses severly restrict the value of the study.

Rosemergy (1967) also conducted a study using sixth graders to determine whether they develop a greater understanding of selected astronomical phenomena from instruction which includes the use of a planetarium than from instruction that does not. He chose seventeen classes of sixth-grade children to receive five periods of instruction in selected astronomical phenomena. The total population was divided into three groups of approximately equal numbers. The treatments were as follows: (1) group A had four periods in the classroom and the last period in the planetarium, (2) group B had the first and the last periods of instruction in a planetarium and three periods in the classroom, and (3) group C received all five periods of instruction in the classroom. These arrangements were thought to reflect the general usage of planetariums in elementary school science instruction.

Rosemergy developed an instrument which was used as both a pre-test and a post-test with each group. This instrument had both content validity

and reliability. It would seem that Rosemergy profited some from the errors made in Smith's study a year earlier. The purpose of the instrument as constructed by Rosemergy was to evaluate the student's understanding of the selected astronomical phenomena. Unfortunately, the objective of the study was stated in the terms of "understanding" rather than behavior, thus it is difficult to conclude if the instrument actually measured the desired objective. Experts had been asked to review the instrument in respect to certain criteria, but unfortunately, it appears that there was no effort made to determine if the test actually measured the objective.

The major conclusions of Rosemergy's study were that each of the three teaching arrangements was effective in increasing the understanding of the selected astronomical phenomena, but that there was no significant difference ($p > .05$) found among the three arrangements. The title of the study is misleading in that the study does not evaluate the effectiveness of the planetarium because Rosemergy never isolated the planetarium as a single variable. In both teaching arrangements involving the planetarium, the variable was compromised by the addition of homework, classroom instruction, and models. The planetarium accounted for only forty percent of the time in one teaching arrangement, and only twenty percent of the teaching time in the other. Otherwise, the conclusion derived from the study with respect to the three teaching arrangements was apparently experimentally and statistically sound and consistent with the purpose as stated (Reed, 1970).

In the same year Soroka (1968) designed a similar study to determine if the planetarium made a significant contribution to the achievement of eighth grade students in the fields of space relations, astronomy, and geography. He divided the sample population into two matched treatment groups. One group was taught a unit of astronomy in the classroom and the other group received instruction in both the classroom and the planetarium. (The number or frequency of planetarium visits is not given in the article.) Soroka stated that the purpose of the study was to determine the relationship of the scores of the two groups of students participating in classroom presentations.

The control groups took part in a supervised study period while the experimental group attended the planetarium presentation. This would indicate that the experimental group had more exposure to the astronomical concepts than the control group. However, a recent communication which this author had with Soroka revealed the article to be somewhat in error and that during the study period the control group was reviewing the same material that the experimental group was receiving in the planetarium. Soroka concluded from this study that the planetarium was an effective educational device ($p < .05$) and made a positive contribution to the understanding and comprehension of basic astronomical and geographical concepts. However, it is important to note that no attempt was made to isolate individual factors of the planetarium program or to evaluate these factors.

Wright (1968) expanded the idea of a variable planetarium lecture schedule by conducting a study using eighth grade students to determine

the effectiveness of teaching a unit of astronomy when it is supplemented by (1) a planetarium program, (2) a planetarium program, prepared by the teacher and a follow-up exercise, and (3) a planetarium program, prepared by the planetarium lectured and a follow-up exercise. The testing instrument was Barnard's seventy-five item true-false astronomy test supplemented by five additional items constructed by a committee of three eighth grade science teachers in the Lincoln Public Schools and Wright investigator.

The four treatment groups used in this study were as follows: Group I took the test at the completion of the astronomy unit, but before attending the planetarium. Group II attended the planetarium before taking the test, but who had no special preparation or follow-up activities. Group III had special preparation by the teacher and a follow-up exercise in addition to the planetarium program before taking the test. Group IV had special preparation by the planetarium lecturer and a follow-up exercise in addition to the planetarium program before taking the test.

Wright (1968) found a statistically significant difference ($p < .01$) between students who had not attended the planetarium programs and students who had attended the planetarium programs with the latter group being superior. She also reported no statistically significant difference ($p > .05$) in achievement between students who had special preparation and follow-up activities with the planetarium program and those who had only experienced the planetarium program. In addition, Wright found no significant difference ($p > .05$) in achievement between students who had special preparation by the teacher and those prepared by the planetarium

lecturer. In the treatments Wright attempted to present the same content and information to each of the groups. Unfortunately, the manner of presentation appears to be so varied between groups that a clear cut conclusion is difficult to reach.

While the study demonstrated that the groups attending planetarium lectures performed significantly better than the non-attending group, it should be mentioned that the attending groups received an additional period of instruction. Since there was no significant difference between the groups receiving preparation and follow-up and the group not receiving this additional treatment, the conclusions that this additional treatment was not effective seems valid. Thus, one might hypothesize that it was the planetarium experience that made the difference. It would be interesting to examine the causes responsible for this situation. One might suggest that the concepts were so well explained in the planetarium that any additional lecturing was simply redundant, but this is a separate study in itself. All that can be concluded from Wright's study is that something transpired in the planetarium which made the attending Ss score significantly higher than those non-attending. It would be of great value to know which of the many factors present were primarily responsible for the result.

The previous studies by Tuttle (1966, 1968), Smith (1966), Rosemergy (1967), Soroka (1968), and Wright (1968) represent the first generation of comparative planetarium research. The six studies previously discussed can be categorized as: two favoring the classroom setting, three the planetarium, and one concluding that there is no difference between

instruction which employs the planetarium and that which does not. This is an over simplified statement because of the inherent differences between the studies. However, they are similar enough that this discrepancy becomes very bothersome to the serious researcher. It is logical to inquire as to the reasons for these divergent conclusions.

It appears that all the studies contained a multitude of confounding variables and never was a single element examined alone. To say that either the planetarium or the classroom was a more effective situation for teaching a unit on astronomy was a meaningless statement. There are a great many factors involved in a planetarium presentation and while some may enhance the learning of some concepts, others may lessen the learning of other concepts. The net result of this could either indicate the planetarium setting was superior or inferior to the classroom depending on which concepts were chosen and the manner in which they were taught. Research must be conducted to determine which environment is better for specific concepts and then an astronomy curriculum can be constructed which employs the environment and various types of auxiliary media that most efficiently promote learning.

Reed's 1970 doctoral dissertation brought the comparative type research a more sophisticated plateau. While this does not imply all research after 1970 was in the second generation of development, there are several studies which attempted to examine the specific areas or concepts which the planetarium appears better suited to demonstrate than does the traditional classroom. Reed used college students to compare the effectiveness

of the planetarium to the combination of classroom chalkboard and celestial globe in the teaching of specific astronomical concepts. Effectiveness was defined as the fulfillment of stated behavioral objectives. Reed concluded that: (1) the chalkboard-globe was significantly superior to the planetarium teaching situation with respect to the immediate attainment and retention of specific cognitive behavioral objectives ($p < .05$); and (2) there was no difference in the affective domain between the two teaching situations.

As a consequence of his study Reed was able to draw several implications some of which can be considered as recommendations for further study. They are as follows:

1. A single planetarium visit may not be an effective learning experience. The student may need to become familiarized to this new type learning situation to effectively learn.
2. An astronomy course should not exclusively use the planetarium.
3. A planetarium should be incorporated into a laboratory or classroom facility. It should not be used solely as a celestial demonstration chamber.
4. The value of the planetarium may be in the affective domain. The cognitive concepts, that the planetarium simulates, may not be so difficult as to give it a value in the cognitive domain.

Dean & Lauck (1972) were skeptical of all of the previously mentioned studies since in all cases, planer, two-dimensional, paper and pencil tests had been employed as measuring devices. They stated that a true test of whether or not a student has learned some elements of observational astronomy would have to be conducted out-of-doors using the real sky. Their study compared the teaching of astronomical lessons to one group using the planetarium and to another group using the classroom chalkboard and celestial globe. Dean & Lauck then tested the students orally and individually under the real sky and concluded that the planetarium was superior ($p < .005$). At first their study seems to contradict the work by Reed (1970). However, each study had different behavioral objectives, treatment methods, and sample populations and thus a comparison between them is difficult. Unfortunately, Dean & Lauck failed to accomplish their objective. They did not demonstrate that the paper and pencil test used by Soroka (1968), Tuttle (1968), Wright (1968), Rosemergy, (1967), and Reed (1970) was an improper means of evaluation and the question of which method is better remained unanswered.

Smith (1973) conducted a study which in part answered the question raised by Dean & Lauck (1972) regarding the paper and pencil instrument. In this study, the Ss (third and fourth grade boys and girls) had been taught constellations in the classroom by the means of slides. The evaluation was performed by both paper and pencil instrument and the planetarium sky. Correlations between the two methods of evaluation were substantial enough to imply that for this sample population, the paper and pencil instrument was a proper means of evaluating certain aspects of observational astronomy. This conclusion was based on the

assumption that the planetarium reflects the actual sky. However, there are those who argue that a person who learns constellations in the planetarium may not be able to recognize them in the real sky.

Smith (1974) therefore attempted to explore this problem of transfer to the real sky in his dissertation. This study addressed itself to two unproven but generally accepted opinions about the planetarium as an educational tool. It is assumed by most planetarium researchers that (1) knowledge acquired in the planetarium sky with respect to observational astronomy is directly transferable to the real sky, and (2) the planetarium setting is a strong motivational device which affects both the cognitive and affective domains.

The Ss used in this study represented three age categories: children, teenagers, and adults. The following three treatment situations, all employing identical verbal instruction were employed: (1) teach constellations in the classroom by means of 35mm slides of hand drawn constellations star fields, (2) teach constellations in the planetarium by means of 35mm slides of hand drawn constellations star fields, and (3) teach constellations by means of the planetarium sky. A two group comparison technique was used for each age group. The Ss were evaluated both in the real sky and by means of a paper and pencil instrument.

The major conclusions of Smith's (1974) study were (1) transfer as defined in the study did occur, (2) Ss learning in three dimensional planetarium setting did significantly poor ($p > .05$) than Ss instructed

in the classroom by means of slides when evaluated by a paper and pencil instrument, and (3) the method of evaluation must be considered when any interpretation of that data is considered because the paper and pencil evaluation showed a significant difference but the real sky evaluation did not.

The studies Dean & Lauck (1972), Reed (1970), and Smith (1974) demonstrated that while many researchers were not always completely fulfilling the goals of their study, some were beginning to ask critical questions and were leaving the generalities and surveys behind.

The role of the planetarium which was discussed earlier as a current problem to persons in the planetarium profession was examined by Sunal (1973). His study attempted to evaluate the goals of planetarium educators in order to provide a basis for future decisions concerning the role and value of the planetarium in elementary education. The main purpose of his study was to determine the relative effectiveness of the planetarium, through analysis of changes among second grade children, in attaining certain perceived goals of planetarium educators. Related factors concerning the effect of student and environmental characteristics on student performance were also investigated.

Three different treatment groups were formed and they are as follows: (1) children involved only in a classroom astronomy unit, (2) children in a classroom astronomy-planetarium unit, and (3) children with no instruction in astronomy or planetarium visit. A single fifty-five minute modified discovery planetarium lesson, closely related to

the science text used in the classroom, was given one to the astronomy-planetarium unit students. The astronomy unit and the astronomy-planetarium unit experience each lasted an average of two weeks.

Sunal concluded that the students in the astronomy-planetarium unit experience, tested over a short period involving a planetarium experience, showed significant gains in all goal areas when compared to students who had no instruction in astronomy or planetarium visit experience tested over a similar period. The astronomy unit experience was also found to be effective in producing change in the goal areas of planetarium educators. However, the astronomy-planetarium unit experience did not produce results in any goal area which were significantly better than the astronomy unit experience ($p < .05$).

It was also found that increased performance in higher order cognitive and affective goals occurred when the planetarium visit took place during the last half of a classroom astronomy unit, compared to other times. Six weeks after a planetarium experience, increased perception and understanding of science principles and processes were noted. Depending on the use of the planetarium in different situation all, some, or none of the preconceived goals of planetarium educators were achieved. The planetarium experience appears to perform as a remedial and reviewing agent changing student performance in a short period.

Curriculum Studies

Studies which dealt with the operation of the planetarium, comparing it to the traditional classroom, and methods of evaluation have been

discussed, but planetarium related curriculum another important aspect remains to be examined. The planetarium had so long been the domain of traditional astronomy that the traditional astronomy curriculum was employed without question. However, by the late fifties this was beginning to change as planetarium educators attempted to examine various ways in which to present astronomical and other concepts to both children and adults.

Several authors have commented on the integration of the planetarium with general science or space science curricula and various other special interest subjects. In general they have concluded that the planetarium was as vital a part of educational equipment as was a physics or chemistry laboratory (Bishop, 1969; Field, 1971; Fowler, 1960; Geiger, 1970; Hennig, 1973; Heyde, 1972; Jagger, 1959; Martin, 1967; Mayer, 1965; Moore, 1967; Noble, 1964; and Roberts, 1970). As one might suspect, most articles dealing with curriculum are directed toward some specific audience which ranges from first graders to adults. In addition many of these articles are subjective in nature and describe a curriculum developed by a small group of persons for use only at one school or district. Usually little if anything has been done to examine if the curriculum fulfills the intended behavioral objectives or can be adapted to other schools or other types of students.

One of the major problems in designing a curriculum for the elementary schools and one for which only limited research has been conducted is the determination of children's understanding of astronomy concepts at

specific levels (Howard, 1968; Yuckenberg, 1962). The lack of substantive research was not a result of a lack of interest on the part of educators, but in many cases reflects disagreement in terminology. At present there appears to be several different interpretations to the word "understanding" (Yuckenberg, 1962).

Yuckenberg (1962) conducted a study to examine what pre-instructional knowledge first grade children had acquired concerning certain concepts of the sun, moon, day and night, and gravity and to find a basis upon which to further develop the understanding of these concepts. Her major conclusion was that children at this level already have some information about these concepts and that it is possible to establish a foundation in the first grade for much of the astronomical understandings in the later grades.

Since the elementary teachers determine in large part what astronomical concepts are taught, Howard (1968) and Sunal (1968) attempted to discover which concepts the teachers considered important for the grades; kindergarten through third. By means of administering a questionnaire Howard and Sunal found that there was some overlapping of concepts between grades. Yet, there was an evolutionary sequence from grade to grade. More concepts were presented with each succeeding grade and these became increasingly sophisticated. Sunal found, for example, that in the kindergarten a few of the teachers discussed time as determined by the sun. By the first grade a greater number of teachers were doing so, and by the third grade the study of time using the stars was taught by the majority of teachers.

Howard and Sunal stated that in general the kindergarten teachers wanted the planetarium to illustrate the sun's daily motion, demonstrate day and night, briefly introduce the moon, and to point out that the earth is only a small part of the universe in which the children live. Children of this age were also found to be able to absorb some idea of the change in the seasons as reflected in the sky.

At the first grade level the teachers were beginning to introduce distance concepts. They discussed how time is reckoned, the fact that the earth rotates, and that this results in the apparent motion of the celestial bodies. At this age the children have an interest in, and are able to handle simple descriptions of the planets, the stars, the solar system, and are beginning to include in their vocabulary words such as horizon. altitude, revolution.

Second grade teachers explained in greater detail some of the concepts taken up in the first grade, discuss constellations and the differences in brightness, color, and distances of stars. The solar system's over-all description, the shapes, sizes, distances of the planets, the positions of the earth, and the moon, and an introduction to space travel and its economy and politics are also introduced.

In the third grade, the study of eclipses was introduced and more emphasis was given to planetary motion. Seasonal constellations were still very important and more of them are brought to the attention of the students along with some of the associated legends. Howard and Sunal

discovered that while the rotation of the earth during the day, the sun's apparent motion, is taught in the kindergarten, the idea that the earth continues to rotate at night is not emphasized much before the third grade.

The list of astronomical concepts introduced by the third grade is certainly impressive. Unfortunately, there was no basis other than the teachers subjective opinions as to how well the students actually grasped these ideas.

Akey (1973) continued the work of Howard (1968) in order to examine the selection of behavioral objectives for planetarium concepts which are appropriate for second grade students. He used the one-group pre-test post-test design with six classes to assess the appropriateness of behavioral objectives prepared for each of the three planetarium programs presented to second graders. Eleven to sixteen objectives were written for each program and these covered all major concepts presented in the planetarium. He then constructed evaluation instruments by using the criterion tests written into each behavioral objective.

One of Akey's major findings support Howard's study in that thirty-nine of the fifty-six major concepts presented in the three programs were significantly understood by the second graders prior to their planetarium experience. Also, Akey concluded that even second graders can learn astronomical concepts by showing that fifty-two of the fifty-six major concepts presented in the three programs were significantly retained by the students after a two week time lapse. Unfortunately, there may be some grounds for questioning Akey's second conclusion. It seems that

he has equated retention with learning. Yet, it appears that Akey's behavioral objectives do provide a basis for adequately evaluating the student's knowledge of selected astronomical concepts.

Prior to the demonstration that students of a specific grade level could learn certain astronomical concepts, several authors were professing diverse methods of instruction. Well known authors such as Samples (1964) and Muhl (1970), after considering the nature of knowledge and learning in relationship to teaching elementary grades in the planetarium, have suggested that lectures must be designed such as to enable a dialogue between student and instructor. In general, the planetarium experience must become an integral extension of the classroom.

Several other authors (Hennig, 1973; Reed, 1971, 1972; Thompson, 1968; Tuttle, 1968) extended the work of Samples (1964) and Muhl (1970) and concluded that the inquiry teaching approach was a method well suited to the planetarium. Working in the same direction, The Middle Atlantic Planetarium Society (MAPS) pointed out as early as March, 1968, that planetarium lesson plans should be developed that would complement the new science curriculum projects. The Earth Science Curriculum Project (ESCP), in particular, had been swamped with requests for planetarium-related materials. The MAPS then organized a Curriculum Committee to address itself to this task. The committee, with the help of Dr. Marjorie Gardner from the Science Teaching Center at the University of Maryland and the assistance of the National Science Foundation, formed the Cooperative College School Science (CCSS) Program (MAPS, 1973).

The CCSS program consisted of a 1970 summer phase of six weeks and four weekend meetings during the 1970-71 academic year for planetarium directors. The specific objectives of this summer phase were as follows: (1) to provide planetarium teachers with experience and training in using the process-centered inquiry approach exemplified in the ESCP program, Investigating the Earth, and related materials; (2) to strengthen the academic background of the planetarium teacher in astronomy and other related earth-space disciplines; (3) to develop lessons and methodology necessary for the effective utilization of the planetarium classroom as a supporting agent in implementing new programs in science as they are introduced into the participant's respective school district; (4) to experiment with "ask-and-do" planetarium programs as contrasted with "show-and-tell;" (5) and to encompass disciplines such as geophysics, geography, and meteorology for planetarium presentation.

By the end of the summer phase over one hundred inquiry-oriented lessons had been written. It was then decided that at least five of the best lessons would be tested by each participant during the academic year phase of the program and records of student and classroom teacher responses were kept to form a basis for revision.

Acting on the belief that the "inquiry-oriented" approach is a suitable and effective method of instruction, the CCSS program was expanded to include fifteen classroom teachers who represented the various science curriculum projects including Time, Space, and Matter (TSM), Introductory Physical Science (IPS), Elementary Science Study (ESS),

Science-A Process Approach (AAAS), Harvard Project Physics (HPP), and Physical Science Study Committee Physics (PSSC). The selected teachers worked in teams with planetarium directors. This ensured the interaction necessary to develop the type of program that would be useful to the classroom teacher.

During the second phase of the program the planetarium directors and classroom teachers directed their discussions to some of the problems that are inherent in planetarium education. Both groups agreed that scheduling was the most arduous task. The teachers could not predict when they would reach a particular unit that enabled them to utilize the planetarium and the planetarium directors had to prepare their schedules in advance since the planetarium facilities served the entire student body. Together the groups had reached the conclusion that more time spent in advance preparation and correlation of material would help alleviate the problems caused by a planetarium lesson that had little relevance to the classroom discussion.

As a result of these opinions, the committee decided that the need for the adoption of a standard format for the various planetarium lessons was imperative. It was recognized that the development of a consistent format would require a clear statement of the purpose of each lesson, as well as the objectives to be accomplished. This in turn required a definition of the background and preparation needed on the part of the student, the materials necessary for the lesson, and a feedback mechanism to evaluate the effectiveness of the lesson.

Using the new format as a guide, the participants of the summer program developed new lessons to be incorporated into the classroom curriculum. These lessons were then modified and correlated with the lessons that had been developed during the previous summer. The fruits of these efforts were to be realized in 1973 with the publication of "Under Roof, Dome and Sky." This was a manual of 45 student-centered activities which represented the best inquiry oriented curriculum available for the instruction of astronomical concepts in the planetarium. Unfortunately, it appears that while a great deal of work has gone into the development of this curriculum and that records were kept, there is no evidence that any formal evaluation measures were ever conducted.

Heyde (1972) working with the Madison Township Public School system in New Jersey went a step beyond the CCSS curriculum when he proposed a model of strategies for planetarium instruction. The planetariums of the Madison Township Public School system were considered as specialized classrooms for the purpose of extending the environment of the student to include the vastness of space.

In this model various degrees of preplanning was required by the classroom teacher and sometimes the students in preparation for the planetarium visit. The classroom teacher, with the assistance of the planetarium instructor, may involve the total class or any part of the class in acquiring skills and attitudes which are necessary to maximize knowledge that can best be gained in the planetarium. The philosophy was to present concepts either in the classroom or planetarium depending on which environment produces the most beneficial results.

Heyde perceived the Madison Township Public School model as having five definite levels of quality of instruction for planetarium utilization in relationship to the classroom, the learners, the classroom teachers, and the planetarium personnel. A "level of quality" of instruction indicates a series of levels within an overall program where the first level would be considered minimally acceptable with levels progressing toward the "ideal" educational program. The ultimate level of quality of instruction that occurs in relationship with the planetarium was that each classroom would utilize the planetarium in the same way it would the slide projector, a piece of chalk and blackboard, a protractor, or any other resource in the school which would enhance the learning process of the student (Chamberlain, 1970; Heyde, 1972; Rey, 1971).

The rationale for Heyde's model was based on both the ideas of Piaget as interpreted by Bonham (1967) and Flavell (1963) and that of Gagné (1965). Heyde agreed that mental growth is similar to a biological process in which the organizational structures develop by assimilating experiences into further mental structures. The richness of the experience to which a learner was exposed appears to have a direct relation to the rate of his cognitive development. He suggested that using the planetarium, as a resource for extending the student's environment, as well as the level of quality of instruction on which the teacher and learner operate was an experience that can further the student's opportunity for growth.

The classroom teacher by use of the planetarium invites and encourages the learner to use other modes of inquiry of investigation. Thus, the learner can expand upon his principles of scientific methodology. By demonstrating the phenomena and theories in planetarium education, the facility automatically becomes a laboratory for developing techniques of scientific thinking (Chamberlain, 1970; Gagné, 1965; Heyde, 1972).

Heyde believed that an atmosphere can be created within the planetarium which provides opportunities to reinforce learner skills such as: listening, identifying, looking, performing, verifying, classifying, etc. As these skills become refined, a modification of behavior can become observable. A portion of Piaget's learning theory--activity, curiosity, flexibility, and exploration--then become subdivisions of the educational process.

Heyde's model appears to be sound with respect to some learning theories and it seems that in his opinion the model worked well in the school system even though no formal evaluation was conducted. Unfortunately, Heyde has made one very serious error. He does not know which concepts are best developed in the planetarium because this area has not yet been fully researched. The basis for the selection of concepts to be taught in one or the other of the environments seems to be purely subjective.

Other Studies

There have been a few interesting articles which are not of the traditional descriptive, comparative, or curriculum type. These will be considered in this section.

Pitluga (1968, 1969) has determined guidelines for achieving the maximum impact of the planetarium on science learning in elementary and secondary schools. He suggested that maximum impact implies a visit by every elementary child to the planetarium three times a year during his elementary school career for presentations related to the science taught in the classroom. The high school students as part of the instruction in their Earth Science, Mathematics, Physics, English, or perhaps in Biology classes should visit the planetarium once each year.

There was good evidence according to Pitluga (1968) that a planetarium lecturer cannot properly offer more than four programs per day. Using these criteria he concluded that a community with a total school enrollment of 9,000 can maintain a program of maximum pact. Fifteen thousand students can be handled at a medium level, and 24,000 plus students receive only minimum impact from a single planetarium.

Articles concerning the use of the planetarium in relationship to the stimulation of the slow learner have been written by Kratz (1969) and Martin (1967, 1969). These authors concluded that with proper preparation and instruction slow learners can enjoy the planetarium experience and retain much of what they have been taught. Kratz (1969) stated that the below average student learned better in the planetarium and was

stimulated to do outside work. In addition as a result of the planetarium's ability to hold his interest the slow learner did not in general present a discipline problem.

The need for formal evaluation techniques in the planetarium has long been recognized (Noble, 1964) but only recently have planetarium personnel begun to take the first steps at designing these methods (Gates, 1973). Notable persons in the field (Branley, 1964; Gallagher, 1970; Gates, 1973; Warneking, 1970) have spoken out in favor of formal assessment. In speaking of future evaluations in the planetarium, Warneking (1973) stated that it will not be easy since the evaluation of educational programs in the planetarium was still an undeveloped science and that to evaluate the vast number of different varieties of planetarium programs would require a wide range of statistical methods and research designs.

Warneking cautioned the researcher to (1) be sure that he is evaluating the effectiveness of the devices used rather than that of the teaching personnel, and (2) be aware of the "cue" theory when testing recall of factual material. He implied that a class tested for recall in the same surroundings as that in which the instruction was initially received will do better than one tested in a different setting because of the presence, in the former case, of certain cues, such as the chalkboard upon which to visualize information, drawings, listings--or spatial relations associated with the past locations of models, charts, graphs, or bulletin boards. In addition Warneking stated that the researcher must realize that the traditional testing for facts does not

constitute a complete job of assessing the full influence of the planetarium lecture because the whole area of the affective domain remains to be examined.

There have been two doctoral dissertations (Battaglini, 1971; Guilbert, 1972) which used the planetarium in formal evaluation studies, but unfortunately in these studies the planetarium served only as the setting for the major purpose of the investigation. Battaglini's 1972 study supported the necessity for the Cooperative College School Science (CCSS) curriculum mentioned earlier. This study was conducted as a result of the need to evaluate the Science Curriculum Improvement Study (SCIS) program at the fourth grade level. The SCIS program attempted to introduce science materials and concepts compatible which children's reasoning abilities by providing equipment for the children's own investigations, and by giving freedom to discover the value of the concepts for themselves.

The SCIS unit titled "Relativity" was the particular unit under investigation. This unit consisted of four parts. The first two parts deal with relative position and the last two with relative motion. The main concept through the entire unit was that relative motion is a change in relative position.

In order to evaluate the effect of this unit, an examination had to be created that was not of the traditional style of a written test. An alternative to the written test was a planetarium oriented evaluation process whereby the student is shown examples of relative position and

motion that are different from those examples previously seen in the classroom. In this novel setting the student would have to depend less on recall and more on his ability to understand the concepts of the unit "Relativity." It was concluded that the fourth graders exposed to this unit had a significantly greater ability to understand the concepts of relative position and motion than a comparable group of students who had not received such instruction ($p < .05$).

Guilbert (1972) conducted a study which greatly improved the level of evaluation of astronomical concepts. He developed a standardized test in collegiate descriptive astronomy on selected concepts which can be demonstrated in the planetarium because no standardized test in astronomy existed at the time. Although it was a standardized test designed for classroom instructed astronomy, it appears to be well suited to the evaluation of astronomical concepts taught in the planetarium. Perhaps this instrument can be used to evaluate the effectiveness of various types of curriculum and methods of presentation in the planetarium.

Unfortunately, it was only applicable to certain concepts and a specific group of students. Guilbert recommended that:

(1) normative data be continually collected,

(2) users of the test compute local norms,

(3) the behavioral objectives and test items be continually revised,

(4) parallel forms of the test be developed,

(5) and standardized tests in astronomy be developed for primary and secondary school students.

When this is done formal evaluation procedures of planetarium and classroom instruction of astronomical concepts will have significantly advanced.

RECOMMENDATIONS FOR FUTURE RESEARCH

This review of planetarium related literature has uncovered many research studies which were poorly executed and indicated areas which are in need of further research. As a result of the vastness of the planetarium domain the list of suggestions for future research appears at present to be endless. Therefore, this author has selected only those aspects of the planetarium which seem to be most in need of immediate research upon which to make recommendations. These recommendations are discussed below.

(1) There exist several similar studies such as those by Rosemergy (1967); Smith (1966); Soroka (1968); Tuttle (1966, 1968), and Wright (1968) which have reported conflicting results as to the value of a planetarium experience for teaching astronomy. The apparent reasons for the differing conclusions may be attributed to poor designs and the introduction of confounding variables. Therefore, it is suggested that these deficiencies to be corrected and that the studies be replicated in an effort to establish a solid foundation on which to conduct further research.

(2) The literature has shown that a multitude of astronomical concepts are being taught to elementary students (Akey, 1973; Howard, 1968; Yuckenberg, 1962). Consequently, it is of value to determine which astronomical concepts can be presented most advantageously in the planetarium or in the classroom and at what grade levels these concepts may be appropriately taught.

(3) Studies by Kratz (1969) and Martin (1967, 1969) have indicated that planetarium programs appear to be especially effective in schools with children of low socio-economic backgrounds. Hence, research should be carried out to isolate which of the many factors at work in the planetarium are responsible for this occurrence. With this knowledge it should be possible to design a special curriculum for low SES groups around these factors.

(4) The studies dealing with disadvantaged children have implied that perhaps more than the cognitive domain was important. Reed (1970) suggested that the true value of the planetarium may be in the affective domain as a result of the planetarium's ability to stimulate students. This is definitely an area in need of much further investigation.

(5) One of the most critical problems yet to be resolved is the issue of single or multiple planetarium visits. This is important because of the money involved for busing children to the planetarium. It is necessary to determine the minimum number of visits required to produce a desired level of comprehension.

(6) It has been mentioned that there is a need to know which concepts can be best developed in the planetarium. However, since the planetarium is a multi-media-sensory environment (Ray, 1971) any particular concept can be demonstrated in a variety of ways. Therefore, it is necessary as in the case of Reed (1970), and Smith (1973, 1974) to evaluate specific kinds of apparatus as to their value for enhancing the learning of these concepts. Because these auxilliary apparatuses represent a

this is also an area in which it is necessary to establish some knowledge per dollar guidelines.

(7) Another technical problem of planetarium programs which has generated conflicting opinions but one for which there has been little in the way of formal evaluations is that of live versus taped lectures (Gallagher, 1970). It appears that tapes lectures are of value but it remains to be determined just when and how they should be employed.

(8) The Cooperative College School Science curriculum has made an immense contribution to the area of the planetarium curriculum. However, there is still a need to coordinate the facilities of the planetarium with various other approaches to the teaching of science at all educational levels.

(9) Even though the work of Guilbert (1972) has brought one aspect of formal evaluation in the planetarium to a new plateau with the development of a standardized test additional research is necessary to produce other standardized instruments. Some of these should be parallel forms of Guilbert's instrument. Also methods of evaluation need to be established and standardized for all aspects of the planetarium.

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